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BACKGROUND OF THE INVENTION

Field of Invention

5 The present invention pertains to the field of
decision analysis. More particularly, this invention
relates to modeling decision-maker preferences.

Art Background

10 A variety of problems commonly involve making
choices among available alternatives. Such choices
usually involve tradeoffs among the available
alternatives. For example, an alternative may be better
in terms of one dimension such as speed, privacy, or
purchase price, etc and worse in terms of another
15 dimension such as footprint, recency of data, or
proximity to customers, etc. An analysis of a choice
among available alternatives commonly involves an
analysis of tradeoffs along many different dimensions.

20 Prior techniques for making choices among available
alternatives commonly involve a determination of an
optimal linear weighting for the values of the various
dimensions. Unfortunately, it is often not clear how to
optimize with respect to any given dimension. In
25 addition, it is often the case that the desirability of
an alternative is contingent on a combination of several
different dimensions. As a consequence, the
determination of an optimal choice among the available
alternatives is typically a major activity that is
30 generally reserved for major decisions which are made
infrequently.

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Prior techniques for making choices among available alternatives may involve eliciting a quantitative estimate from decision-makers as to the relative importance of different dimensions. Unfortunately, decision-makers are typically not proficient at assigning such quantitative estimates. For example, it is usually not clear to a decision-maker whether the cost of an alternative is twice, or three times, etc., as important as the throughput yielded by the alternative. As a consequence, prior techniques which take into account such quantitative estimates are subject to errors.

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Techniques are disclosed for modeling the preferences of a decision-maker using sampled pair-wise preferences. These techniques involve identifying a set of alternatives to be presented to the decision-maker and identifying a set of attributes associated with the alternatives. The alternatives are each characterized by a set of values for the attributes. A sample set of pair-wise preferences among a subset of the alternatives is obtained and a model of preferences is generated by iteratively generating a set of candidate models and evaluating the candidate models using a fitness measure which is based on the sample set of pair-wise preferences. The models may take into account characterization attributes associated with potential decision-makers. For example, the decision maker 14 has an associated set of characterization attributes 60-62.

20 The preference models yielded by these techniques
may be used in a wide variety of systems and devices to
render choices among available alternatives while
automatically taking into account the modeled
preferences of the relevant decision makers. Such
25 systems include presentation systems including those
used in business and e-commerce as well and product
support systems, software distribution systems, web
server systems including e-commerce web servers. In
addition, preference models yielded by these techniques
30 may be used in systems and devices which render such
choices on behalf of particular decision-makers. Such
systems include web agents and may include hand-held

devices and/or mechanisms implemented in software on computer systems.

5 Other features and advantages of the present invention will be apparent from the detailed description that follows.

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BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is described with respect to particular exemplary embodiments thereof and reference
5 is accordingly made to the drawings in which:

Figure 1 shows a system for generating a preference model according to the present techniques;

10 **Figure 2** shows steps involved in generating a preference model from sample pair-wise preferences;

Figure 3 shows steps involved in evolving a preference model using genetic programming techniques;
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Figure 4 shows steps involved in constructing a new population of candidate models from the current population of candidate models;

20 **Figure 5a-5c** show a new candidate model which is generated by combining a pair of candidate models of a current population.

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DETAILED DESCRIPTION

Figure 1 shows a system 10 for generating a preference model 12 according to the present techniques. The preference model 12 is a model of the preferences of a decision-maker 14 with respect to a set of alternatives 20-22. The alternatives 20-22 have corresponding sets of attributes 30-32, 40-42, and 50-52, respectively. The alternatives 20-22 differ by the values v1-v3, v4-v6, and v7-v9 assigned to the attributes 30-32, 40-42, and 50-52, respectively. The preference model 12 is generated by a modeler 16. The modeler 16 takes as input information from the decision-maker 14 and/or a set of other decision-makers 18.

The decision-maker 14 may be a human being or a non-human animal. Likewise, the other decision-makers 18 may be human beings or non-human animals.

The preference model 12 once generated may be used to determine or predict the preferences of the decision-maker 14 or groups of decision-makers with respect to any combination of the alternatives 20-22 or of alternatives having similar attributes. Numerous applications and uses of the preference model 12 are possible.

For example, the alternatives 20-22 may be different alternatives of similar available products which are characterized by different set of values for the attributes of price, brand name, size, packaging, etc. In this case, the preference model 12 may be used to predict which of the available products the decision-

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of pair-wise preferences obtained at step 76. Step 78 in one embodiment is performed using genetic programming techniques.

5 **Figure 3** shows steps involved in evolving the preference model 12 using genetic programming techniques in one embodiment. At step 80, a population of the candidate models is constructed. Each candidate model is capable of expressing a modeled pair-wise preference
10 between any two of the alternatives 20-22 in response to the corresponding values v1-v3, v4-v6, and v7-v9 assigned to the corresponding attributes, 30-32, 40-42, and 50-52.

15 The candidate models may be computer programs. The computer programs may each be represented as a tree or as a sequence of computer instructions or in any other manner that may be used to represent computer programs. Alternatively, the candidate models may be mathematical
20 expressions each represented as a tree. In other alternatives, the candidate models are neural networks or belief networks.

25 In one embodiment, the candidate models express a modeled pair-wise preference by returning a number representing a utility value for each alternative. An example candidate model may return the following (example utility values) for alternatives A, B, and C:

30 A=0.5
 B=0.4
 C=0.01

 At step 82, the candidate models from the population are evaluated using a fitness measure that

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model 12. The accuracy to which the selected candidate model agrees with the sample set of pair-wise preferences is freely selectable.

5 The step of evolving (step 78) continues by constructing a new population of candidate models and repeating steps 80-84 for the new population. This loop of constructing new populations and repeating steps 80-84 for each new population continues until a candidate
10 model is found that meets the termination criterion.

Figure 4 shows the steps involved in constructing a new population of candidate models from a current population of candidate models. At step 90, a subset of
15 the candidate models from the current population is selected based on the fitness measures. For example, the subset of candidate models having fitness measures that agree most closely with the sample set of pair-wise preferences may be selected at step 90. At step 92, a
20 set of candidate models for a new population is generated by combining portions the candidate models selected at step 92. The selected candidate models may be combined using operations which are modeled on the genetic operations of mutation and/or cross-over.

25 **Figure 5a-5c** show a new candidate model 120 which is generated by combining a pair of candidate models 100 and 110 of a current population. In this example, the candidate models 100 and 110 each provide a tree
30 arrangement of nodes that represents a mathematical function involving variables x, y, and z. The variables x, y, and z represent values for the attributes associated with the alternatives 20-22.

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The candidate model 100 includes an arrangement of operator nodes 200-204 and input nodes 210-215. The operator nodes 200-204 specify add, multiply, subtract, subtract, and multiply operators, respectively. The
5 input nodes 210-215 specify x, x, z, y, a constant value equal to 3, and x inputs, respectively. The candidate model 100 provides a tree representation of the mathematical function $f(x,y,z)=x^2+3xy-z$. The candidate
10 model 110 includes an arrangement of operator nodes 300-306 and input nodes 310-317 that represents the mathematical function $f(x,y,z)=(x+z+y)(y-z)(32y+4)$.

The new candidate model 120 is formed by cutting the operator nodes 300, 302, and 304-306 and the input
15 nodes 313-317 from the candidate model 110 and combining them with the operators nodes 202-204 and input nodes 212-215 which are cut from the candidate model 100. The new candidate model 120 represents the mathematical function $f(x,y,z)=(3xy-z)(y-z)(32y+4)$.

20 In an alternative embodiment, the preference model 12 may take into account characteristics associated with decision-makers. A method in the system 10 for generating the preference model 12 in the alternative
25 embodiment includes a step of identifying a set of characterization attributes that may be associated with the decision-maker 14 and a step of obtaining a sample set of values for the characterization attributes from the decision-makers from which the sample set of pair-
30 wise preferences are obtained at step 76. The step of obtaining the sample values for the characterization attributes may be performed using a set of multiple

choice questions which are presented to the appropriate decision-makers.

5 The step 80 of constructing a population of
candidate models in the alternative embodiment involves
constructing candidate model each capable of expressing
a modeled pair-wise preference between any two of the
alternatives in response to the values for the
attributes as well as the values for the
10 characterization attributes. For example, candidate
models which are mathematical functions such as those
described above are functions of c_1, c_2, \dots, c_n as
well as x, y , and z , i.e. $f(x, y, z, c_1, c_2 \dots c_n)$ in the
alternative embodiment.

15 The step 82 of evaluating the candidate models in
the alternative embodiment involve examining the modeled
pair-wise preferences of each candidate model over a
subset of the alternatives and decision-makers and
20 deriving a fitness measure which includes at least one
criterion that penalizes the candidate models for
disagreeing with the combination of the sample set of
pair-wise preferences and corresponding sample values
for the characterization attributes.

25 A system 10 may be incorporated into a system for
designing a presentation. This enables design of the
presentation by selecting between available
alternatives. In such systems, the preference model 12
30 is constructed for a particular target audience using
the techniques described herein.

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carried out by the device. The means in the device for obtaining physical measurements may be any conceivable measurement means such as bar-code readers, temperature sensors, or other types of sensors, etc. The device may
5 include any type of storage means such as memory for storing the preference model 12.

The modeler 16 or system for designing a presentation which is based on the modeler 16 may be
10 embodied as a computer program or as a web-based service executing on one or more computer systems, possibly networked, or other types of devices with processing resources. The alternatives 20-22 may represent one or more products or services offered for sale by one or
15 more suppliers. The products or services may be offered for sale over a computer network. The alternatives 20-22 may represent taking or not taking an action. The action may be the installation of software on a computer system.

20 The alternatives 20-22 may represent ways of customizing a product or service. The product or service may be a computer program. The product or service may be obtained over a computer network. The
25 customization options may reflect different available degrees of quality of service including, for example, price, security, privacy, reliability etc., as well as performance.

30 The foregoing detailed description of the present invention is provided for the purposes of illustration and is not intended to be exhaustive or to limit the invention to the precise embodiment disclosed.

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Accordingly, the scope of the present invention is defined by the appended claims.

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